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G. Chen, J. Zhou

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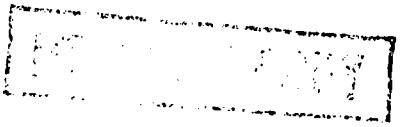
Drs. G. Chen and J. Zhou investigated various problems in the analysis, control, optimization and computation of structural mechanical systems and distributed parameter systems in general. In particular, they developed the wave method and boundary element methods and used functional analysis to study partial differential equation models of plates, solids and fluids, and other abstract mathematical systems.



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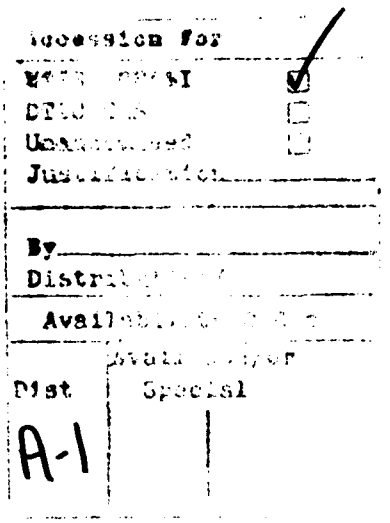

Submitted by the

TEXAS A&M RESEARCH FOUNDATION
Box 3578
College Station, TX 77843

to the
Department of Defense
Air Force Office of Scientific Research

Prepared by

Dr. G. Chen
Professor of Mathematics and Aerospace Engineering
Department of Mathematics
Texas A&M University

and

Dr. J. Zhou
Assistant Professor of Mathematics
Department of Mathematics
Texas A&M University

Goong Chen
Goong Chen, Principal Investigator
Phone: (409) 845-7336

Jianxin Zhou
Jianxin Zhou, Co-Principal Investigator
Phone: (409) 845-2927

Joann Treat
Joann Treat, President
Texas A&M Research Foundation

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Final Technical Report of AFOSR Grant 87-0334

"Stabilization and Control Problems in Structural Dynamics"

Report Period: September 1, 1988-December 31, 1990

Table of Content Page

I. Review of Achievements and Annual Progress

During the grant period September 1, 1988-December 31, 1990, Dr. G. Chen, the P.I., and Dr. J. Zhou, the co-P.I., along with graduate students and scientific collaborators, have studied various facets of stabilization and control problems in structural dynamics. The research results have been submitted to scientific journals and presented at professional meetings. Some award of recognition* has also been received. For the summary of achievements during the previous period September 1, 1988-December 31, 1989, please refer to our Annual Technical Report sent to AFOSR in February 1990. Therefore in this report, we will describe primarily the progress made by us in the past calendar year.

Fourteen scientific publications supported by this grant are listed in §II. We have

i) 5 new articles published (cf. [1]-[5])

ii) 6 articles accepted (cf. [6], [7], [8], [10], [11], [13])

iii) 3 articles currently in revision or pending (cf. [9], [12], [14]).

The types of problems treated in these articles can be divided as follows:

a) The wave method for the analysis of damping and stabilization ([2], [3], [7] and [10])

b) Analysis of vibration eigenfrequencies of plates ([8])

c) Boundary element methods, control and optimization of solids and (linear Stokes) fluids ([1], [4])

d) New stabilization theorems, holomorphic semigroup properties ([6], [9])

e) Optimization, variational inequalities, convex analysis and games ([11]-[14]).

These topics encompass a broad range of interest in the analysis, optimization, control and stabilization of structural mechanical systems and other general distributed systems. Overall speaking, we have stayed closely in course of the planned directions.

A new grant (#AFOSR 91-0097) has been approved to support the continuing research of the P.I.s over the next three years (January 1991-December 1993). We are grateful to

* G. Chen, along with collaborators Drs. P.J. Morris and T.R.S. Bhat, were given an AIAA Certificate of Merit for the outstanding technical paper "Shock structure in jets of arbitrary exit geometry" at the AIAA 12th Aeroacoustics Conference in April 1989.

the project monitors and program managers at AFOSR for the generous assistance and support given to us during the various phases of our work. In the forthcoming period (1991-1992), although we expect our work to emphasize *fluid and structure interactions*, and *nonlinear control*, we will also try to maintain a good balance between *theory and analysis, computation* and *application* at the same time.

Our scientific collaborators are listed in alphabetical order in §III. Research activities are described in §IV.

II. List of Publication and Status

During the period January 1- December 31, 1990, the following research articles have been published:

[1] G. Chen and J. Zhou, "Boundary element method for shape control of distributed parameter elastostatic systems", in AIAA Progress in Aeronautics and Astronautics Series Vol. 129, J.L. Junkins ed., pp. 315-348, AIAA, Washington, D.C., 1990.

[2] G. Chen, S.A. Fulling, F.J. Narcowich, and C. Qi, "An asymptotic average decay rate for the wave equation with variable coefficient viscous damping", SIAM J. Appl. Math., 50 (1990), 1341-1347.

[3] G. Chen and J. Zhou, "The wave propagation method for the analysis of boundary stabilization in vibrating structures", SIAM J. Appl. Math. 50 (1990), 1254-1283.

[4] L. Ji and J. Zhou, "The boundary element method for the boundary control of the linear Stokes flow", Proc. of the 29th IEEE-CDC, 1192-1194, Honolulu, December, 1990.

[5] G. Chen, E.B. Lee, W. Littman and L. Markus, "Distributed Parameter Control Systems – New Trends and Applications", Lecture Notes in Pure and Appl. Math. Series, Vol. 128, Marcel Dekker, New York, 1990. (516 pages in total.)

Reprints of the above publications with Report Documentation Pages are also hereby attached for the Program Manager.

The status of several other recent papers by G. Chen and J. Zhou is given below.

[6] G. Chen, S.A. Fulling, F.J. Narcowich and S. Sun, "Exponential decay of energy

of evolution equations with locally distributed damping", SIAM J. Appl. Math., to appear, 1991.

[7] G. Chen and H.K. Wang, "Asymptotic locations of eigenfrequencies of vibration of an Euler-Bernoulli beam with nonhomogeneous structural and viscous damping coefficients", SIAM J. Control Opt., to appear 1991.

[8] G. Chen, M.P. Coleman and J. Zhou, "Analysis of vibrating eigenfrequencies of a thin plate by Keller-Rubinow's wave method", SIAM J. Appl. Math., to appear 1991.

[9] F.L. Huang and G. Chen, Differentiable and holomorphic properties of the C_0-semigroup associated with a vibrating distributed system with unbounded damping", SIAM J. Control Opt., in revision.

[10] J. Zhou and G. Chen, "The wave method for determining the asymptotic damping rates of eigenmodes (I): the wave equation on a rectangular or circular domain", SIAM J. Control Opt., to appear 1991.

[11] G. Tian and J. Zhou, "Quasivariational inequalities with non-compact sets", to appear in J. Math. Anal. Appl.

[12] M.R. Baye, G. Tian and J. Zhou, "Characterizations of the existence of equilibria in games with discontinuous and nonquasiconcave payoffs: theory and applications", revised manuscript pending in Econometrica.

[13] G. Tian and J. Zhou, "The maximum theorem and the existence of equilibrium in abstract economies without lower semicontinuity", to appear in J. Math. Anal. Appl.

[14] J. Zhou and G. Tian, "Transfer method in characterizing the existence of maximal elements for binary relations on compact or non-compact sets", SIAM J. on Optimization, in revision.

III. Personnel

Dr. G. Chen is the principal investigator in charge of the overall conduct of the grant. Dr. J. Zhou is the co-principal investigator. With regard to the research in this grant, Dr. Chen works primarily on the PDE theory, stabilization, engineering models and applications, while Dr. Zhou works on the aspects of optimization, scientific computation and computer graphics. This collaboration enables the P.I.s to cover many different types

of distributed parameter control problems of contemporary interest.

The ranks and affiliations of scientific collaborators in Section II are given below:

1) M. Baye, Associate Professor, Dept. of Econ., Texas A&M Univ., College Station, Texas.
2) M.P. Coleman, Assistant Professor, Dept. of Math. and Comp. Sci., Fairfield Univ., Fairfield, Connecticut.
3) S.A. Fulling, Professor, Dept. of Math., Texas A&M Univ., College Station, Texas.
4) F.L. Huang, Associate Professor, Dept. of Math., Sichuan Univ., Chengdu, China.
5) L. Ji, Ph.D. student, Dept. of Math., Texas A&M Univ., College Station, Texas.
6) E.B. Lee, Professor, Dept. of E.E., Univ. of Minnesota, Minneapolis, Minnesota.
7) W. Littman, Professor, Dept. of Math., Univ. of Minnesota, Minneapolis, Minnesota.
8) L. Markus, Regent's Professor, Dept. of Math., Univ. of Minnesota, Minneapolis, Minnesota.
9) F.J. Narcowich, Professor, Dept. of Math., Texas A&M Univ., College Station, Texas.
10) C. Qi, Ph.D. student, Dept. of Ind. Eng., Pennsylvania State Univ., Univ. Park, Pennsylvania.
11) S. Sun, Professor, Dept. of Math., Sichuan Univ., Chengdu, China.
12) G. Tian, Assistant Professor, Dept. of Econ., Texas A&M Univ., College Station, Texas.
13) H.K. Wang, Assistant Professor, Dept. of Math., Wichita State Univ., Wichita, Kansas.

IV. Activities

Drs. G. Chen and J. Zhou have given the following invited presentations at universities, national/international meetings of professional societies and workshops:

1) G. Chen, AIAA Dynamics Specialist Conference, "The boundary element method for shape control of distributed parameter elastostatic problems", Long Beach, California, April 1990.

   Individual involved: Prof. J.L. Junkins.

2) G. Chen and J. Zhou, SIAM 1990 National Meeting, "The boundary element method for the boundary control of distributed parameter systems", Chicago, July 1990.
Individuals involved: Profs. D.L. Russell and R.L. Wheeler.

3) G. Chen and J. Zhou, The Fourth International Conference on the Control and Identification of Distributed Parameter Systems, "Some boundary control problems and computation of the linear elastostatic Kirchhoff plate on an exterior domain", Vorau, Austria, July 1990.
Individuals involved: Prof. F. Koppel and K. Kunisch.

4) G. Chen, Rep. of China-South Africa Symposium on Differential Equations, "Analysis of vibration eigenfrequencies of a thin plate by Keller-Rubinow's wave method", Taipei, Taiwan, August 1990.
Individual involved: Prof. Sze-Bi Hsu, Tsing Hua Univ., Hsinchu, Taiwan.

5) G. Chen, M.P. Coleman and J. Zhou, IFIP Workshop on Boundary Control and Variations, "Analysis of vibration eigenfrequencies of a thin rectangular plate", Sophia-Antipolis, France, October 1990.
Individuals involved: Drs. J.P. Zolesio and J. LeBlonde.

6) L. Ji, J. Zhou and G. Chen, The 29th IEEE-CDC, "The boundary element method for boundary control of the linear Stokes flow", Honolulu, December 1990.
Individual involved: Dr. G. Knowles.

7) G. Chen, invited seminar at the Math. Dept., North Carolina State Univ., Raleigh, "Analysis and stabilization of vibration of a thin plate", March 1990.
Individuals involved: Profs. J. Dunn and E. Chukwu.

8) G. Chen, invited seminar at the Math. Dept., Univ. of Nevada-Las Vegas, "The boundary element method for the shape control of elastostatic systems", April 1990.
Individual involved: Prof. J. Shiue.

9) G. Chen, invited seminar at the Math. Dept., Univ. of Houston, "A survey of some recent results in the control of thin plates", September 1990.
Individual involved: Prof. G. Auchmuty.

Dr. Chen also co-chaired an invited session entitled "Nonlinear and Boundary Control of Systems Governed by Partial Differential Equations", at the 29th IEEE-CDC in

Honolulu in December 1990.

During July 20-August 20, 1990, Dr. Chen was an invited guest lecturer at the Institute of Applied Mathematics, National Tsing Hua University in Hsinchu, Taiwan, where he gave a month long short course on boundary integral equations and boundary element methods for elliptic partial differential equations.